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Super-Light Prefabricated Deck Element Integrated in Traditional Concrete Prefabricated Element Construction.

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Summary

Super-light structures in form of deck elements have been used for the first time in a building to construct indoor pedestrian bridges.

Examples of connections to external structures and other super-light deck elements are given along with other details. Other examples on the great versatility of the super-light slab element are element size, which have greatly reduced the total number of elements the pedestrian bridges consist of. The application also demonstrated the ability to control the path that the forces will take in the element. The deck elements are for example fully prepared at the factory for sustaining concentrated forces from single point bearings.

Keywords: *Super-light structures; Slab element; Pre-fabricated elements.*

1. Introduction

The concept of super-light structures was invented in 2007 by the co-author Kristian Hertz. The principles of the ideas behind super-light structures are described in [1-3]. The main feature of super-light structures is to combine a strong and stiff load carrying material with a light material in order to optimize the material consumption and weight of building elements. The whole idea behind this concept is emerged from considerations on static behaviour of concrete arches. General advantages of super-light slab elements include: Material savings, lower weight, improved fire safety, reduced CO₂-consumption, improved sound insulation, improved sound absorption, reduced transport cost and enhanced possibility of design.

In a deck structure with limited height it is hard to establish full element length arches within the element because the horizontal forces from the flat arches becomes too large. To solve these problems the slabs are constructed from several arches which directs the forces onto the desired paths. This is done by casting lightweight aggregate concrete blocks with a density of 600 kg/m³ and an outer box dimension of 500x400x185mm. These blocks are placed in an array and normal concrete is cast in the cavities between them creating the arches above them and crossing ribs between them with slack and prestressed wires. Furthermore the relatively thin layer of normal concrete above the blocks constitutes a compression zone of the slab. At the end is a solid block of concrete with a width of 100mm placed for the anchorage of the prestressed reinforcement and to ensure optimal support conditions. This method of casting means that a self compacting plastic concrete can be used. A conceptual drawing of the deck element is shown on Fig. 1.

A larger series of experimental tests have been conducted on the element, namely bending, shear, pull-out of reinforcement, acoustical and fire test. All tests were used to compare theoretical calculations with experimental results and all theory used was verified, this is described further in [4] and in [5] the acoustical tests are described in depth.

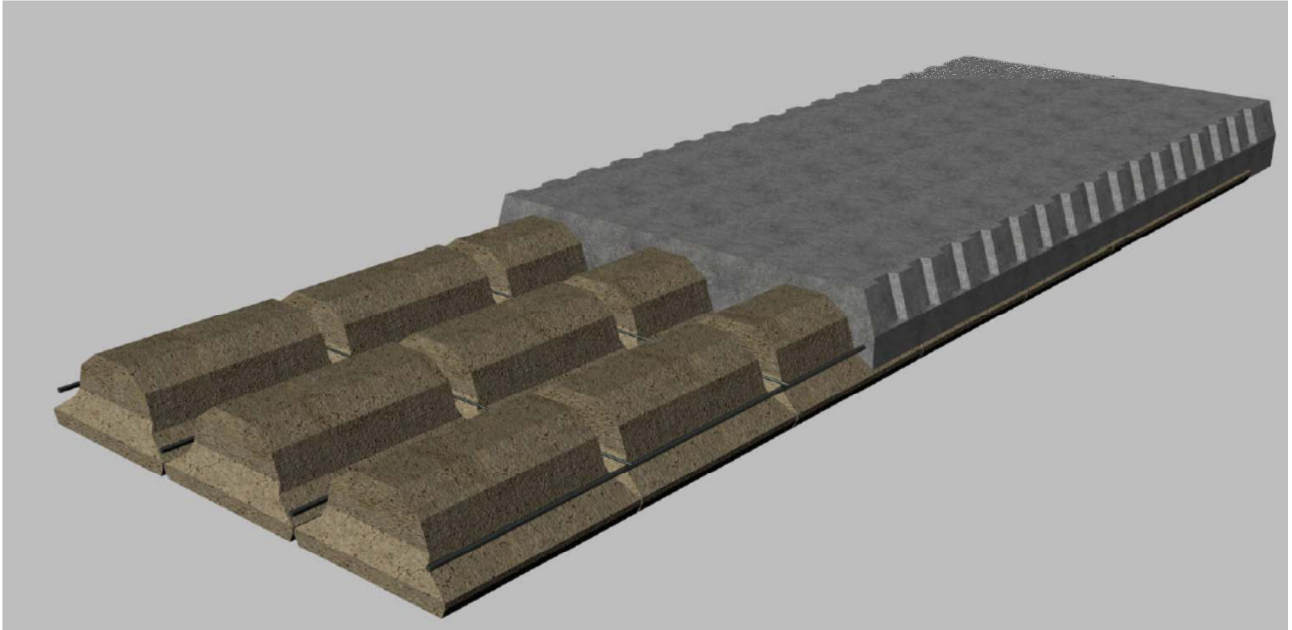


Figure 1: Conceptual drawing of a super-light element.

For the current project of indoor pedestrian footbridges a more varied geometry of slab element has been used and therefore the elements have been cast in custom-made formwork. In combination with short spans between supports the elements are cast with only slack reinforcement. Within the slab elements it is possible to establish concrete beams with beam reinforcement and control the static behaviour of the element. Where no need for special reinforcement or steel embedment parts exists blocks of lightweight aggregate concrete is placed to greatly reduce element weight.

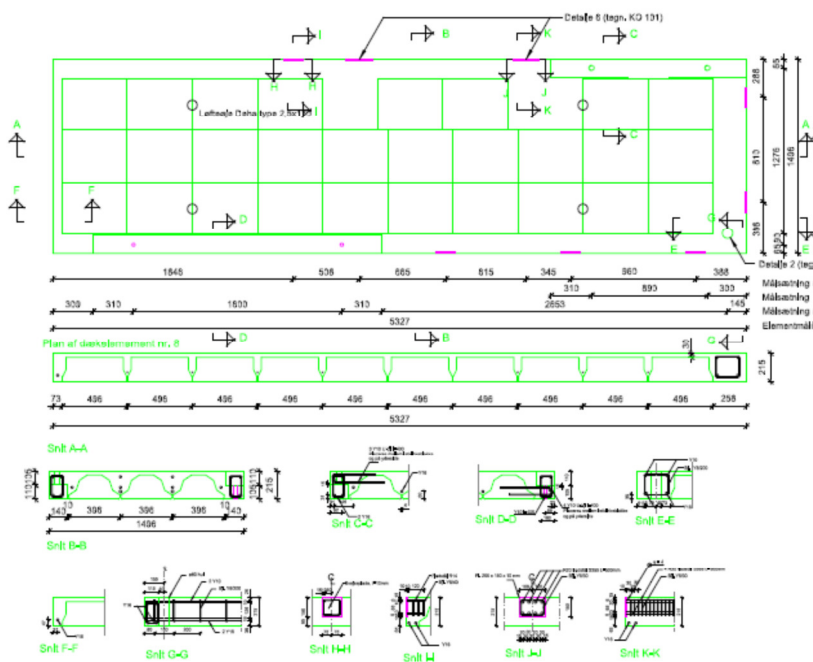
2. Indoor Pedestrian Bridge and Element

2.1 Element

In order to accommodate the need for elements with a custom width the concept of edge beams have been introduced. This is a block of solid concrete along the edges of the super-light element. Here extra reinforcement is placed and if needed full beam reinforcement can be placed here as well. The beam reinforcement is used near supports and to strengthen the element. The edge part of the cross-section made of a solid concrete allows for connection details which are not possible to make in hollow core or other similar concrete elements.

Furthermore at each of the supports cross-beams have been establish within the element by making a gap of approximately 300mm between the ends of the lightweight aggregate blocks and having beam reinforcement in that cavity between light-aggregate blocks.

On Fig. 2 a picture and a working drawing is shown. Here the setup for a typical element can be seen before normal concrete is cast on it. The production drawing shows the placement of lightweight aggregate blocks along with reinforcement, consoles, and steel embedment parts.



2.2 Plan

On the big squares the predetermined support points were too few in order to design prefabricated super-light deck element to be stable and not obtaining large negative moments while keeping the width of the elements below 3000mm which is a requirement when transporting the elements on

public roads. It was not possible to accommodate the problems by post-tensioning of the elements due to the method by means of which the elements should be mounted. Another proposed solution was to in-situ cast the element as one big plate 10x5m, but this was neglected since the desire of having it all build up from prefabricated elements was strong. Therefore a few steel beams have been installed underneath the super-light elements in order to establish a line support of the elements in these special areas.

2.3 Details

Several common concrete details have been incorporated in a unique way into the super-light deck elements. These includes steel hangers connected through holes in the super-light element, the use of inserts in connection details, consoles to make the mounting of the elements easy in a straightforward manner, and finally welding plates to connect elements with supports on exterior steel elements.

2.3.1 Hangers connection

One of the support types of the pedestrian bridge are steel hangers suspended from steel beams in the roof. The detail is shown on Fig. 4 below.

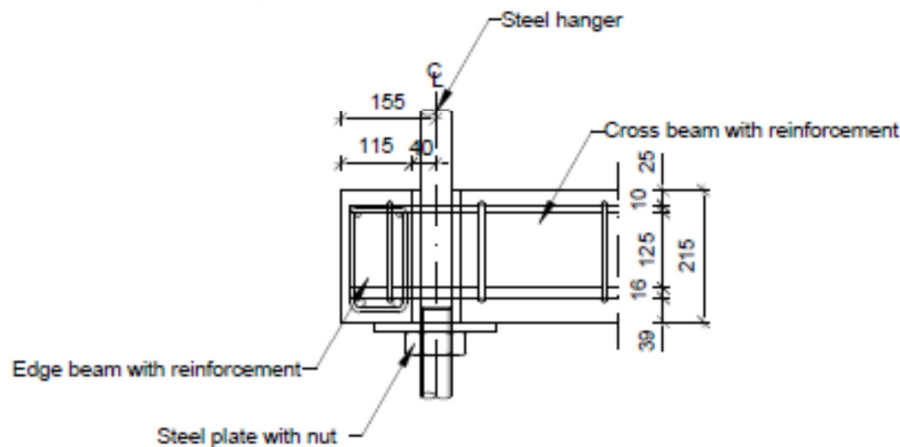


Figure 4: Hanger connection.

It is shown how the hanger passes through the element. The hole is encased in beam reinforcement in two directions and in a full section of normal concrete to obtain the strength of the element at the support. The rather large stiff steel plate distribute the load from the support over a large area to eliminate the risk of punching shear and further increase the anchorage of the longitudinal reinforcement in both directions at the supports. Where the steel hanger is supporting a continuous element at the middle, and a negative moment therefore appears, extra top reinforcement has been installed to accommodate the negative moment.

2.3.2 Insert connections

Another method of support is by casting embedded steel parts such as inserts. This can create a strong bolted group in the edge beams of the concrete. The general setup is shown on Fig. 5. A few variants of this are present in the actual building, where an adjacent wall functions as a support to the pedestrian bridge.

Again as it was the case for the hanger connection the area around the support has been supplied with a double array of beam reinforcement in the super-light slab which would be unthinkable for example in extruded hollow-core slabs.

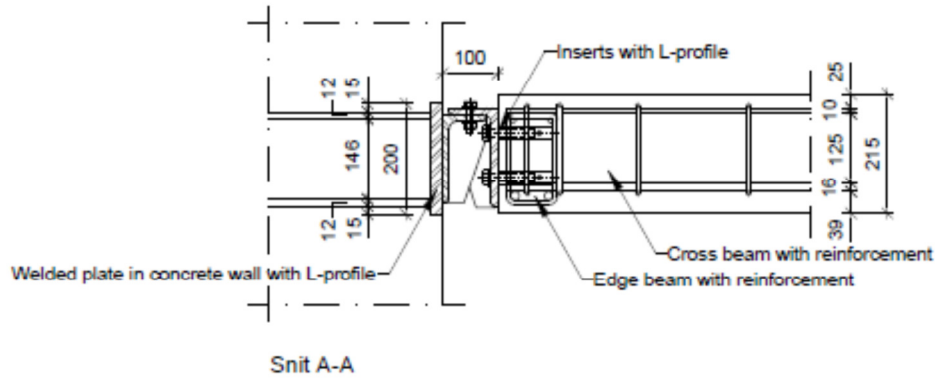


Figure 5: Insert connection.

2.3.3 Console connection

The super-light elements are connected with each other through an overlapping console connection. If it is needed due to the supports, this connection can be locked together by a countersunk steel pad and a nut. By having the elements connected to each other like this, the need for casting concrete in-situ is greatly reduced, only a little is used in the oversized holes to disallow movement between the two slabs.

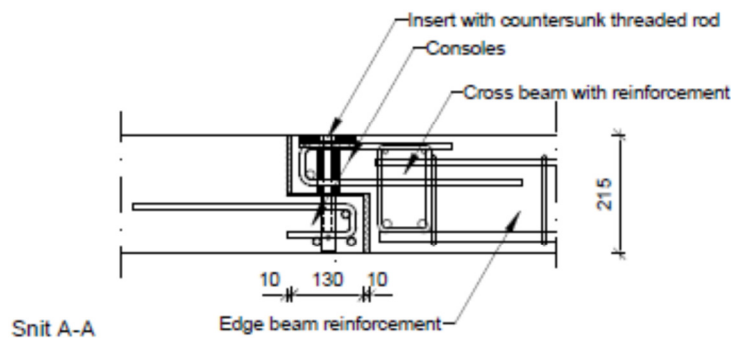


Figure 6: Console connection

Furthermore, it also simplifies the mounting process of the elements by eliminating the risk of having an incorrect mounting sequence. The elements simply would not fit if they are not mounted correct.

2.3.4 Welding plates

The use of welding plates in the elements is challenging since the edge beams can be as narrow as 100mm, this does not leave much space for anchoring the welding plate. However, by utilising the block geometry it is possible to find a height of the plate, different from the element height that balances the applied moment on the welding plate with the maximum anchoring capacity in the concrete. A 150x150x10mm plate is placed at the top of the element in order to optimize the depth of the anchorage while having a sufficient distance between the rods to reduce the tension force from the moment, which needs to be anchored.

3. Comparison with a more Traditional Construction System

The super-light deck elements for the indoor pedestrian bridges were chosen in competition with a more traditional proposal consisting of a combination of hollow-core concrete elements and steel profiles.

The base of the hollow-core element proposal is built by a supporting steel frame structure made of L-profiles and carrying the outlines of the bridge at the positions where edge beams and cross beams were established in the super-light deck element design. So in a way the static system concerning the carrying of the bridge is similar for the two proposed systems. But in the super-light elements this is dealt with internally making the mounting of the elements easier.

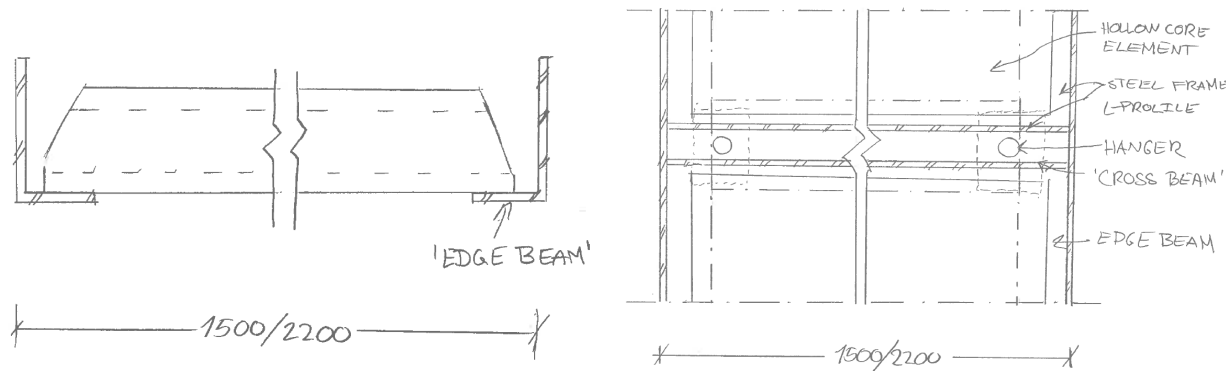


Figure 7: Sketch of edge and cross beams in traditional hollow-core elements proposal

With the hollow core proposal a larger number of short hollow-core elements with a width of 1200mm is needed to span from one L-profile to another. This accounts for a large amount of element mountings and lifting and with a lot of joints between the hollow-core elements needing to be filled with grouting mortar, making the work process involved with installing of the pedestrian bridge much larger. Another problem arises in the case of fire for the hollow core elements. In order to have sufficient anchorage of the reinforcement the hollow cores in the slabs near supports needs to be filled with grouting mortar in a distance of two times the height, for 1500mm long elements this accounts for more than one fourth of the element that should be cast out as a massive concrete slab. This excessive amount of extra work could be avoided by adding costly exterior fire protection to the elements.

Another advantage of the super-light deck elements being used is significant environmental benefits and savings on CO₂ consumptions. The combination of lightweight concrete and normal concrete already accounts for less CO₂ emission compared to normal concrete elements. Adding the steel L-profiles pushes CO₂ emission numbers much more in favour of the super-light elements.

4. Conclusion

The technology of super-light deck elements have successfully been implemented into a new building as indoor pedestrian bridges spanning between the main towers of the building.

The super-light elements used in this project have a width between 1500mm and 2700mm and is therefore a slightly modified version of the 1200 or 2400mm wide element that have been developed to be mass produced. The modification consist of addition of edge and cross beams, which enhances the strength of the element by adding the possibility of introducing beam reinforcement

Several special details to create the boundary conditions of the super-light elements have been developed and implemented. These details depend on the possibility of having solid sections of concrete present in the element, giving the necessary strength and stiffness to account for holes and forces from the supports and hanger connections.

5. Acknowledgements

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6. References

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